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March 5, 1857.

The LORD WROTTESLEY, President, in the Chair.

In accordance with the Statutes, the Secretary read the following list of Candidates for Election into the Society:—

Thomas Graham Balfour, M.D.	Rev. Thomas Kirkman.
Robert Ball, LL.D.	Henry Lethaby, M.B.
Henry Foster Baxter, Esq.	Waller Augustus Lewis, M.B.
Lionel Smith Beale, M.B.	George Macilwain, Esq.
Samuel Husbands Beckles, Esq.	David Macloughlin, M.D.
Charles Tilstone Beke, Ph.D.	William Marctet, M.D.
George Boole, Esq.	John Marshall, Esq.
Edward M. Boxer, Capt. R.A.	John Penn, Esq.
Samuel Brown, Esq.	William Peters, Esq.
George Bowdler Buckton, Esq.	Lieut. Bedford Pim, R.N.
Thomas William Burr, Esq.	Andrew Smith, M.D.
William Dingle Chowne, M.D.	Robert Angus Smith, Esq.
William Coulson, Esq.	Warington Wilkinson Smyth, Esq.
Thomas Russell Crampton, Esq.	Charles Piazzi Smyth, Esq.
Richard Cull, Esq.	Henry Clifton Sorby, Esq.
Thomas Davidson, Esq.	John Welsh, Esq.
Hugh Welch Diamond, M.D.	Thomas Williams, M.D.
James Dixon, Esq.	Joseph Whitworth, Esq.
S. W. Fullom, Esq.	Forbes Benignus Winslow, M.D.
William Bird Herapath, M.D.	Bennet Woodcroft, Esq.
Rowland Hill, Esq.	James Young, Esq.
George Grote, Esq.	

The following communication was read :—

“On what the Colonial Magnetic Observatories have accomplished.” By Major-General SABINE, R.A., Treas. and V.P.R.S. Received February 26, 1857.

It has been suggested to me, that a brief review of what has been accomplished by the Colonial Magnetic Observatories, instituted on the joint recommendation of the Royal Society and British Association, would be acceptable; and that the officer who has been entrusted with the superintendence of these establishments is the person from whom such a review may most properly be expected. Fully assenting to both propositions, I have readily undertaken the task; and have availed myself of the occasion to add a few remarks and suggestions on the measures which appear to be required for the further prosecution of the objects for which the observatories were recommended.

The magnetic investigations designed to be carried into execution by the Colonial Observatories recommended by the Royal Society embraced a much wider scope than had been contemplated by any previous institutions, or than had been provided for by the arrangements or instrumental means of any then existing establishment, whether national or private. Not, as previously, limited to observations of a single element (the Declination),—or combining at the most one only of the components of the magnetic force,—the instructions of the Royal Society, and the instrumental means prepared under its direction, provided for the examination, in every branch of detail, of each of the three elements which, taken in combination, represent, not partially but completely, the whole of the magnetic affections experienced at the surface of the globe, classed under the several heads of absolute values, secular changes, and variations either periodical or occasional,—and proceeding from causes either internal or external. To meet the requirements of inductive reasoning, it was needful that the results to be obtained should comprehend all particulars under these several heads, attainable by an experimental inquiry of limited duration. That no uncertainty might exist as to the objects to which, in so novel an undertaking, attention

was to be directed, the Report of the Committee of Physics, approved and adopted by the President and Council of the Royal Society, stated in a very few sentences, remarkable alike for their comprehensiveness and conciseness, the desiderata of magnetical science. It may be convenient to reproduce these, when desiring to show the degree in which the Observatories have fulfilled their contemplated purposes :—“The observations will naturally refer themselves to two chief branches, into which the science of terrestrial magnetism in its present state may be divided. The first comprehends the actual distribution of the magnetic influence over the globe, at the present epoch, in its mean or average state, when the effects of temporary fluctuations are either neglected, or eliminated by extending the observations over a sufficient time to neutralise their effects. The other comprises the history of all that is not permanent in the phenomena, whether it appear in the form of momentary, daily, monthly, or annual change and restoration ; or in progressive changes not compensated by counter-changes, but going on continually accumulating in one direction, so as in the course of many years to alter the mean amount of the quantities observed.”—Report, pp. 1, 2.

With reference to the first of these two branches, viz. the actual distribution of the magnetic influence over the globe at the present epoch, the Report goes on to state :—“The three elements, viz. the horizontal direction, the dip, and the intensity of the magnetic force, require to be precisely ascertained, before the magnetic state of any given station on the globe can be said to be fully determined and as all these elements are at each point now ascertained to be in a constant state of fluctuation, and affected by transient and irregular changes, the investigation of the laws, extent, and mutual relations of these changes is now become essential to the successful prosecution of magnetic discovery.”

With reference to the second branch, viz. the secular and periodical variations, it is observed that—“The *progressive* and *periodical* being mixed up with the *transitory* changes, it is impossible to separate them so as to obtain a correct knowledge and analysis of the former, without taking express account of and eliminating the latter;” and with reference to the secular changes in particular, it is remarked—“These cannot be concluded from comparatively short series of observations without giving to those observations extreme

nicety, so as to determine with perfect precision the mean state of the elements at the two extremes of the period embraced ; which, as already observed, presupposes a knowledge of the *casual* deviations."

It is clear from these extracts that in the discussion of the observations the first point, in the order of time, ought necessarily to be an investigation into "the laws, extent, and mutual relations of the *transient* and," (as they were called at the time the Report was written,) "*irregular* changes," as a preliminary step to the elimination of their influence on the observations from which a correct knowledge and analysis of the progressive and periodical changes were to be obtained. It will be proper to show therefore, in the first place, what the Observatories have accomplished in regard to the so-called *casual* or *transitory* variations.

Casual Variations.—All that was known regarding these phenomena at the period when the Report of the Committee of Physics was written, was, that there occurred occasionally, and, as it was supposed, irregularly, disturbances in the horizontal direction of the needle, which were known to prevail, with an accord which it was impossible to ascribe to accident, *simultaneously* over considerable spaces of the earth's surface, and were believed to be in some unknown manner connected, either as cause or effect, with the appearances of the aurora borealis. The chief feature by which the presence of a disturbance of this class could be recognized at any instant of observation,—or by which its existence might be subsequently inferred independently of concert or comparison with other Observatories,—appeared to be, the deflection of the needle from its usual or normal position to an amount much exceeding what might reasonably be attributed to irregularities in the ordinary periodical fluctuations. The observations which had been made on the disturbances anterior to the institution of the Colonial Observatories had been chiefly confined to the declination. A few of the German Observatories had recently begun to note the disturbances of the horizontal force ; but as yet no conclusions whatsoever had been obtained as to their laws : in the words of the Committee's Report, the disturbances "apparently observe no law." By the instructions cited above, the field of research was enlarged, being made to comprehend the disturbance-phenomena of the *three* elements ; and the importance of their examination was urged, not

alone as a means of eliminating their influence on the periodic and progressive changes, but also on the independent ground, that "the theory of the transitory changes might prove itself one of the most interesting and important points to which the attention of magnetic inquirers can be turned, as they are no doubt intimately connected with the general causes of terrestrial magnetism, and will probably lead us to a much more perfect knowledge of those causes than we now possess."

The feature which has been referred to as furnishing the principal if not the only certain characteristic of a disturbance of this class, viz. the *magnitude* of the departure from the usual or normal state at the instant of observation, has, in the discussion of the observations, been made available for the investigation of their laws: it has afforded the means of recognizing and separating from the entire mass of hourly observations, taken during several years, a sufficient body of observations to furnish the necessary data for investigating at three points of the earth's surface—one in the temperate zone of the northern hemisphere, a second in the temperate zone of the southern hemisphere, and a third in the tropics—the laws or conditions regulating or determining the occurrence of the magnetic disturbances. The method by which this separation has been effected has been explained on several recent occasions, and will be found fully described in the Phil. Trans. for 1856, Art. XV. By processes of this description, the disturbances of principal magnitude in each of the three elements, the Declination, Inclination and Total Force, have been separated from the other observations, at the three observatories of Toronto, Hobart and St. Helena, and submitted to an analysis of which the full particulars will be found in the preliminary portions of the volumes which record the observations. By the adoption of a uniform magnitude as constituting a disturbance throughout the whole period comprised by the analysis, the amount of disturbance in the several years, months, and hours is rendered intercomparable. The result of this investigation (which could not be otherwise than a very laborious operation, since the observations at a single one of these stations, Toronto, considerably exceeded 100,000 in number, each of which had to be passed through several distinct processes,) has made known to us that the phenomena of this class, which may in future with propriety

and advantage receive the appellation of "*occasional*," are, in their mean or average effects, subject to periodical laws of a very systematic character ; placing them, as a first step towards an acquaintance with their physical causes, in immediate connexion with the sun as their primary exciting cause. They have—1, a *diurnal* variation which follows the order of the solar hours, and manifests therefore its relation to the sun's position as affected by the earth's rotation on its axis ; 2, an *annual* variation, connecting itself with the sun's position in regard to the ecliptic ; and 3, a third variation, which seems to refer still more distinctly to the *direct* action of the sun, since, both in period and in epochs of maximum and minimum, it coincides with the remarkable solar period of about ten, or perhaps more nearly eleven, of our years, the existence of which period has been recently made known to us by the phenomena of the solar spots ; but which, as far as we yet know, is wholly unconnected with any thermic or physical variation of any description (except magnetic) at the surface of the earth, and equally so with any other cosmical phenomena with which we are acquainted. The discovery of a connexion of this remarkable description, giving apparently to magnetism a much higher position in the scale of distinct natural forces than was previously assigned to it, may justly be claimed on the part of the Colonial Observatories, as the result of the system of observation enjoined (and so patiently and carefully maintained), and of the investigation for which it has supplied the data ; since it was by means of the disturbance-variations so determined, that the coincidence between the phenomena of the solar spots and the magnitude and frequency of magnetic disturbances was first perceived and announced (Phil. Trans. 1852, Art. VIII.).

The extent and mutual relation of the disturbance-variations of the three elements, even at a single station, supply a variety of points of approximation and of difference, which are well suited to elucidate the physical causes of these remarkable phenomena ; but valuable as such aids may be when obtained for a single station, their value is greatly augmented when we are enabled to compare and combine the analogous phenomena, as they present themselves at different points of the earth's surface. To give but a single example :—there are certain variations produced by the mean effects of the disturbances which attain their maximum at Toronto during the hours of the

night ; the corresponding variations attain their maximum, at Hobarton, also during the hours of the night, but with a small systematic difference as to the precise hour, and with this distinguishing peculiarity, that the deflection at Hobarton is of the opposite pole of the needle (or of the same pole in the opposite direction) to the Toronto disturbance ; whilst at a third station, St. Helena, which is a tropical one, the hours of principal disturbance are those not of the night, but of the day. A very superficial examination is sufficient to show that for the generalization of the facts,—a generalization which is indispensable for their correct apprehension and employment in the formation of a theory,—the stations at which the phenomena are to be known must be increased. Those which were chosen for a first experiment were well selected to prove the importance of the investigation, and thus to lead to its extension. It is only at the Colonial Observatories that the disturbance-variations have hitherto been made out ; and taking experience as our guide, we have before us the evidence of the means by which the inquiry may be further successfully prosecuted *.

Periodical Variations.—The anticipation expressed in the Report of the Committee of Physics, that for the purpose of obtaining a cor-

* The Colonial Observatories under my superintendence were originally four in number, viz. Toronto, St. Helena, Cape of Good Hope, and Hobarton. In July 1846 the detachment of the Artillery at the Cape of Good Hope was withdrawn by orders from England, and the charge of the magnetical and meteorological observations transferred to Mr. Maclear, the Government Astronomer at that station. The magnetical observations made at the Cape, when the magnetic observatory was one of those under my superintendence, were published in 1851, with a discussion of certain of their results ; and the disturbance-variation of the declination at the Cape has since been deduced by my assistant, Captain Younghusband, Phil. Trans. 1853, Art. VI. Since the transfer to Mr. Maclear, Mr. Pierce Morton, a gentleman of considerable mathematical attainments, who has been added as an assistant to Mr. Maclear in that branch of the Cape observations, has applied himself to the investigation of the lunar magnetic influence (as derived from the Cape observations), with a view of presenting the results to the Royal Society. For this, and other deductions,—such as, for example, the laws of the disturbances of the inclination and total force,—he will have the entire series of observations, viz. those as above-stated already published, and those which have been made since the transfer of the Observatory, up to the present time.

rect knowledge of the *regular periodical variations*, it would be found necessary to eliminate the "casual perturbations," has been fully confirmed. Had the latter been strictly "casual" (or accidental, in a sense contradistinguished from and opposed to periodical), a sufficiently extended continuance of observation might have occasioned their mutual compensation; but now that we have learned that the mean effects which they produce are governed by periodical laws, and that these laws and those of the regular periodical variations are dissimilar in their epochs, it is manifest that in their joint and undivided effects we have two variations, due to different causes and having distinct laws, superimposed upon each other; *to know the one correctly we must necessarily therefore eliminate the other.* A striking illustration of the importance of such elimination is furnished by the solar-diurnal variation of the total force. It will readily be imagined that the question must be an important one, whether a variation, which is supposed to derive its origin from the sun, be a single or a double progression; whether it have two maxima and two minima in the twenty-four hours, or but one maximum and one minimum in that period. When no separation is made of the disturbances, the progression appears to be a double one, having two minima, one occurring in the day and the other in the night. With the removal of the disturbed observations the night minimum disappears, and we learn that the regular solar-diurnal variation of the total force has but one notable inflection in the twenty-four hours, viz. that which takes place during the hours when the sun is above the horizon. The night minimum is in fact the mean effect of the occasional disturbances. It is probable that the nocturnal inflection of the solar-diurnal variation of the Declination may be ascribed to the same cause, namely to the superposition of two distinct variations.

A careful analysis of the solar-diurnal variations of the Declination at the Colonial Observatories has brought to light the existence at all these stations, of an *annual inequality* in the direction of the needle concurrent with changes in the sun's declination, having its maxima (in opposite directions) when the sun is in or near the opposite solstices, and disappearing at or near the epochs of the equinoxes. An intercomparison of the results of the analysis at these stations has shown, that this inequality has the remarkable characteristics of having notably the same direction and amount in

the southern as in the northern hemisphere, and in the tropical as in the temperate zones. An ingenious explanation of these phenomena has been suggested by Dr. Langberg of Christiania (Proceedings of the Royal Society, vol. vii. p. 434); but whether this explanation be or be not the correct one, the theoretical importance of the facts cannot be doubted, inasmuch as they appear to be wholly irreconcileable with the hypothesis which would attribute the magnetic variations to thermic causation. We may ascribe to the general and almost exclusive prevalence of the thermic hypothesis, and to its influence on magnetic reasonings, that the well-known erroneous opinion was so confidently promulgated by a deservedly high magnetic authority*, that a line *must* exist surrounding the globe, in which the needle would be found to have *no diurnal variation*. We have now, on the contrary, reason to be assured, by the facts of the annual inequality thus discovered, that there is no such line; but that everywhere in the regions of its supposed existence a diurnal variation subsists, having opposite characteristics in opposite parts of the year as influenced by the sun's position on either side of the equator, and disappearing only at the epochs when the sun passes from south to north or from north to south Declination.

Lunar Variation.—But if thermic relations have failed to supply a connecting link between the sun and those magnetic variations which are, without doubt, referable to the *sun* as their primary cause, the failure of that hypothesis is made still more obvious by the existence of variations governed by the *moon's* position relatively to the place of observation. We are indebted to M. Kreil, now holding the same position in Austria that I have filled in England, for the first suggestion of the existence of a lunar-diurnal variation of one of the elements, viz. of the Declination, founded on observations at Milan and Prague; and in the Phil. Trans. for 1856, Art. XXII., will be found an exposition of the facts of the moon's diurnal influence on each of the three magnetic elements at Toronto, viz. on the Declination, Inclination, and Total Force. In the case of this investigation, notwithstanding the smallness of the values concerned, the instrumental means supplied to the Colonial Observatories have been found competent to determine, with an approximation suffi-

* Arago, Annuaire, 1836, p. 284.

cient for present theoretical purposes, the character and amount *for each element* of the regular daily effect of the moon on the terrestrial magnetic phenomena, the existence of which does not appear to have been even suspected at the time when the Report of the Committee of Physics was drawn up. The *discovery* of the moon's influence on any of the magnetic elements is due, as already stated, to M. Kreil ; but Toronto is the first, and as yet the only, station, at which the numerical values at every lunar hour of the lunar-diurnal variations of the three elements have been published. Corresponding statements to that which has been given for Toronto, will be found for St. Helena and Hobarton, in the volumes of those observatories, which are now in preparation. All the results at the three stations present the same *general* characters. The lunar influence does not appear to participate in the decennial inequality which is found in all the solar variations (Phil. Trans. 1857, Art. I.). The lunar-diurnal variation of each of the elements is a double progression in the twenty-four hours, having epochs of maximum and minimum symmetrically disposed. In *character*, therefore, it differs from what might be expected to take place if the moon were possessed of inherent magnetism, *i. e.* if she were a magnet, as it is usually termed, *per se* ; and accords with the phenomena which might be expected to follow if she were magnetic only by induction from the earth. On the other hand, it is believed that the *amount* of the variation, as observed at each of these stations, very far exceeds what can be imagined to proceed from the earth's inductive action reflected from the moon. In this theoretical difficulty we are naturally thrown back to seek a more extensive knowledge of the phenomena than we have yet obtained, and to the generalization which will follow, when sufficient materials for it have been procured. In subordinate particulars, a difference, which is apparently systematic, is perceived to exist in regard to the hours which constitute the epochs of maxima and minima at the three stations, as well as in regard to the amounts of the respective variations ; these differences are no doubt intimately connected with the causes of the phenomena, and are likely to lead to their elucidation. It is therefore greatly to be desired that the number of stations furnishing complete determinations, such as the Colonial Observatories only have hitherto supplied, should be increased.

The domain of periodical variations has thus been considerably enlarged since the Report of the Committee of Physics was drawn up ; and must henceforth be understood to comprise, in addition to the variations " whose amount is a function of the hour-angle of the sun, and of his longitude " (or of his declination) (Report, p. 10),—1st, those variations of the three elements whose amount is a function of the hour-angle of the moon ; 2ndly, those variations which were classed in the Committee's Report as " irregular," or " apparently observing no law," but which are now known to be governed by laws depending on the sun's declination, and hour-angle ; and 3rdly, those variations, both " regular " and " occasional," which have their epochs and amounts dependent apparently on a solar period of not yet perfectly ascertained duration, manifesting itself also by periodical changes in the frequency and amount of the solar spots. With the exception of the last-named class, all these variations require, for their generalization, that the phenomena should be investigated at several points of the earth's surface widely distant from each other ; and we have now the knowledge, grounded on experience, that a very few years are sufficient for the observations at each station, with the instrumental means and methods recommended by the Royal Society, and when the investigation is made a primary object by those who engage in it.

Absolute Values and Secular Changes.—But interesting and valuable as is the acquisition of a fuller and more precise knowledge of the comparatively small magnetic variations produced at the surface of the earth by the action or influence of external bodies, even greater importance seems to attach,—when *terrestrial* magnetism is in question,—to the purposes of that distinct branch of the duties of a magnetic observatory, which consists in the determination of the absolute values and secular changes of the three magnetic elements. By the *absolute values* we seek to acquire a knowledge of the actual present order and distribution of the terrestrial magnetic influence at the surface of the earth, and to provide the materials by which the constancy, or otherwise, of the earth's magnetic charge may hereafter be examined ; and by determinations of the present direction and amount of the *secular changes*, we seek to become acquainted with the laws, and ultimately with the causes, of that

most mysterious change, by which the magnetic condition of the globe at one epoch passes progressively and systematically into that of another. It is specially by determinations of this class, obtained with the necessary precision in different parts of the globe, that, in the words of the Committee's Report, "the patient inductive inquirer must seek to ascend to the general laws of the earth's magnetism." At the time when the Report of the Committee of Physics was written, doubts were reasonably entertained, whether the limited time, during which the Colonial Observatories were likely to be maintained in action, would be sufficient for the determination of the secular changes; and it was therefore very properly argued, that "these changes cannot be concluded from comparatively short series of observations without giving to the observations *extreme nicety*, so as to determine with perfect precision the mean state of the elements at the two extremes of the period embraced." It is with much satisfaction, and with a well-deserved recognition of the pains which have been bestowed by the successive Directors of the Toronto Observatory, and their Assistants, on this branch of their duties, that I am able to refer to the determinations of the absolute values and secular changes of the three elements contained in the third volume of the Toronto Observations, in evidence that the instrumental means which were devised, and the methods which have been adopted, have proved, under all the disadvantages of a first essay, sufficient to determine these data with a precision which is greatly in advance of preceding experience, and, as far as may be judged, equal to the present requirements of theoretical investigation. This is the more deserving of notice, because Toronto is a station where the casual and periodical variations, which it was apprehended would seriously interfere with the determination of absolute values, are unusually large. We may derive, therefore, from the results thus obtained, the greatest encouragement to persevere in a line of research which is no longer one of doubtful experiment, and to give it that further extension which the interests of science require.

Amongst the results which have recompensed the labours of the Colonial Observatories in this branch of their inquiries, perhaps there is none of more importance in respect to the general theory of terrestrial magnetism, than the conclusion which has been established by means of the observations of the Declination at St. Helena, that

the current annual amount of secular change takes place by *equal aliquot portions in every month, and even in every fortnight of the year*. The magnitude of the annual change of the Declination at St. Helena, 8' (or more precisely 7'.93 in each of the eight years in which the observations were maintained), and the comparative tranquillity of the tropical regions in regard to magnetic disturbances, were circumstances which rendered St. Helena a particularly eligible locality for an investigation of this nature. The result has been, to remove secular change altogether from the category of atmospheric or thermic relations, with which, in the absence of a correct knowledge of the facts, it has frequently been erroneously associated ; and to show conclusively that it is a phenomenon of far more systematic order and regularity than has been generally apprehended (Proceedings of the Royal Society, vol. vii. pp. 67-75).

It has thus been shown, that, in each and all of the branches of inquiry for which the institution of the Colonial Observatories was recommended, they have accomplished the objects which were contemplated, and have in many respects exceeded the expectations on which their recommendation was founded. Nor has the scope of their performance been limited to a mere registry of the observations, or to their publication in a crude and undigested form. It was well remarked by an authority of the greatest weight, when addressing the British Association on the occasion of the assembly of the Magnetical and Meteorological Conference at Cambridge in 1845 (Herschel, Address, p. xxxv), that "A man may as well keep a register of his dreams, as of the weather or any other set of daily phenomena, if the spirit of grouping, combining, and eliciting results be absent." To advance by the simple and straightforward path of inductive inquiry, in a science such as terrestrial magnetism in which a physical theory has yet to be sought, the endeavour must be made "to grapple with the palpable phenomena, seeking means to reduce their features to measurement ; the measurements to laws ; the laws to higher generalizations ; and so, step by step, to advance to causes and theories." The mere observational part is not, and ought never to be, viewed as the fulfilment of the duties of institutions such as magnetic observatories ; those duties ought always to be held to include (either on the part of the Directors of the Observatories them-

selves, or on that of persons who, as Superintendents or otherwise, have constantly watched the progress of the work) "the systematic deduction from the registered observations, of the mean values, and of the local coefficients of diurnal, annual, and secular change;" because "no other class of persons stands in anything like so favourable a position for working out the first elementary laws of phenomena, and referring them to their immediate points of dependence," as those who have directed or superintended the processes by which the data required for the knowledge of the phenomena have been obtained. The introductory discussions prefixed to the several volumes which contain the observations at the Colonial Observatories, and a succession of papers presented to the Royal Society, and published in the Philosophical Transactions, bear testimony to at least unsparing labour, on the part of the Superintendent, to give a completeness to the experiment of Colonial Observatories, corresponding to its original conception; though no one is more sensible than himself that this portion of the duty might well have fallen into abler hands. One great advantage in the task has undoubtedly been enjoyed, *viz.* the union of the detailed knowledge above alluded to, with the opportunity of generalization and consequent insight, afforded by results admitting of strict comparison and combination, obtained from well-selected stations at such distant points of the globe, and by a uniform system of observation.

It may be useful on the present occasion to recall to more distinct recollection the views and opinions entertained by those who were the principal instigators of the proceedings by which the Royal Society became the responsible advisers,—and Her Majesty's Government the chief supporters,—of measures which have placed this country in the very conspicuous position of taking that lead in the advancement of certain branches of science, which other nations were willing and desirous that she should take. These views cannot be better stated than in the words of one to whom all will be willing to concede pre-eminence, as well in counselling the recommendation to Government as in conducting the several points connected with it to a successful issue (Herschel, in *Quart. Review*, No. CXXXI.). "Great physical theories, with their trains of practical consequences, are pre-eminently national objects, whether for glory or utility. In effect, such they ought to be considered by every nation calling itself civi-

lized ; and if we look to consequences, we have only to point to the history of science in all its branches to show, that every great accession to theoretical knowledge has uniformly been followed by a *new practice*, and by the abandonment of ancient methods as comparatively *inefficient* and *uneconomical*. This consideration alone we think sufficient to justify, even on utilitarian grounds, a large and liberal devotion of the public means to setting on foot undertakings and maintaining establishments, in which the investigation of physical laws, and the determination of exact data, should be the avowed and primary object, and practical application the secondary, incidental, and collateral one. That the time is now fully arrived when other great branches of physical knowledge must be considered as entitled to share in that public support and encouragement which has hitherto fallen to the lot of astronomy alone, will, we think, be granted without hesitation by all who duly consider the present state and prospects of science. The great problems which offer themselves on all hands for solution—problems which the wants of the age force upon us as practically interesting, and with which its intellect feels itself competent to deal—are far more complex in their conditions, and depend on data which, to be of use, must be accumulated in far greater masses, collected over an infinitely wider field, and worked upon with a greater and more systematized power, than has sufficed for the necessities of astronomy. The collecting, arranging, and duly combining these data are operations, which, to be carried out to the extent of the requirements of modern science, lie utterly beyond the reach of all private industry, means or enterprize. Our demands are not merely for a slight and casual sprinkling to refresh and invigorate an ornamental or luxurious product, but for a *copious, steady, and well-directed stream, to call forth from a soil ready to yield it, an ample, healthful, and remunerating harvest*. There are secrets of nature we would fain see revealed,—resources hidden in her fertile bosom for the well-being of man upon earth, we would fain see opened up for the use of the generation to which we belong. But if we would be enlightened by the one, or benefited by the other, we must *lay on power*, both moral and physical, without grudging and without stint.”

If at the period when it was still doubtful what the Colonial Observatories then just established might be able to accomplish,—and

when, in effect, the expectations from them were little more than the anticipations of what a voyage of discovery upon an unknown ocean might produce,—the propriety of embarking upon such investigations was thus unhesitatingly affirmed, how much more confidently may the duty of *perseverance* be insisted upon, when the results of the first experiment have already more than realized the hopes which caused it to be undertaken. They have indeed confirmed the belief that “the gigantic problem proposed to be resolved” is of a nature to yield in its full extent only to “continued and persevering inquiry;” but at the same time they may be said, in a certain sense, to have narrowed the field of inquiry, by showing more distinctly than was previously apprehended, both what is desired to be known, and how and where it is to be sought. If the history of magnetical science is to be something more than a fragment, the research must be persevered in.

In considering the means by which the researches thus opened out may be most advantageously prosecuted, it is natural that we should look, in the first instance, to the adoption, at other selected stations, of arrangements similar to those which were instituted at the stations which were chosen for a first, and as it has proved, successful experiment; and with this view I may be permitted to restate the opinions which I submitted to the Magnetical and Meteorological Conference at Cambridge in 1845, as all that has since taken place has served to confirm them.

“Before I close this communication, I wish to advert to the expediency of extending the system of observation now in operation at Toronto, St. Helena, and the Cape of Good Hope, to other of the British Colonies, where the same objects can be accomplished in an equally effective and economical manner.

“In cases where the institution of similar establishments is strongly urged by the Governor of a Colony,—where competent persons are present and disposed to superintend the observations, and where soldiers of the Artillery are stationed whose services may be available, and whose employment has been shown to be economical and effective in a high degree in the execution of a laborious and exact routine of observation,—there is wanting only a supply of instruments,—the temporary allotment of a building to contain them,—extra pay, such as the individuals at the above-named Observatories

receive,—and an authorized connexion with a head-quarter establishment whence they may derive instruction and guidance.

“The cost of one of the Ordnance Observatories (including £100 a year for incidentals of all kinds) is £392 a year, exclusive of publication. It may be assumed that five years of hourly observation is a sufficient time of continuance for obtaining in any particular colony the mean values of the magnetical and meteorological elements, and their diurnal, annual, and secular variations, as well as the peculiarities of climate bearing on the health and industrial occupations of man. If the observations were printed *in full detail* for the five years, they would occupy two quarto volumes; but if it were thought sufficient hereafter that duplicate or triplicate manuscript copies should be deposited in different public libraries, and that publication should be confined to abstracts and an analysis, the cost of the publication would form but a small addition.

“The colonies of Ceylon, New Brunswick, Bermuda, and Newfoundland are in the described case; their respective Governors are recommending the establishment of Magnetical and Meteorological Observatories in them; competent directors are on the spot [this was written in 1845]; and they are all Artillery stations.”

To the four stations thus named may be now added Mauritius and Demerara, as from both those Colonies, strong and repeated applications to the same effect have been sent through their respective Governors to the Secretary of State for the Colonies. Both these Colonies have offered to bear a portion of the expense of the proposed establishments; and have earnestly solicited to be placed in connexion with a head-quarter establishment, from which they might receive properly constructed instruments, with instructions and guidance in their use. Can it be said that we perform our duty as a mother-country when we put such applications on the shelf?—whilst, in the interests of science, it would be difficult to estimate too highly the value of such institutions,—in forming good observers, who might subsequently extend their activity over a wider range,—in affording to travelling observers the opportunity of testing and correcting their instruments, as well as keeping up and perfecting their skill in observation,—and in contributing to arouse, to nourish, and to extend to other parts of natural knowledge, that desire for the greatest pos-

sible accuracy, which was formerly met with only in astronomy and in geodesical operations of the highest class.

When it was first suggested that the officers and soldiers of the scientific corps of the army (Artillery or Engineers) stationed in the Colonies might, both beneficially to themselves and advantageously to the public interests, be made available for the performance of such temporary services, the suggestion, from its novelty, might have been open to many objections. None were, indeed, made by the military authorities of the time, who on the contrary approved and encouraged the proposition. There may have been doubts entertained in other quarters whether persons, whose ordinary occupations were so dissimilar, would be found to possess the necessary qualifications for carrying out a scheme of exact and varied observation, in which there was then no precedent to guide, and of which the performance would be sure to be extensively and closely scrutinized: but such doubts, if they existed, have probably long since subsided, as the successive volumes of the Colonial Observatories have appeared.

One great and unquestionable advantage which future institutions of this nature will have over those whose duties are accomplished, will be found in the assistance they will derive from the *Physical Observatory of the British Association* at Kew, as a head-quarter Observatory, in which their instruments can be prepared and verified, the constants, &c. carefully determined, new instruments devised as occasion may require, and tested by experiment before they are sent out for use, and to which practical difficulties of all kinds, which may present themselves to the directors, may be referred.

The omission of a provision of this kind when the Observatories were first formed, was undoubtedly a great fault, which has been, and could only be, very imperfectly remedied by the Woolwich establishment, designed for a very different purpose, and insufficient even for the duties for which it was designed.

There is another advantage (if it be one) which might attend the early prosecution, viz. the opportunity of consulting (if it were desired to consult) the experience of the person who has conducted, —and, as he believes, successfully conducted,—the first experiment,

from its commencement now almost to its close ; but this, in the course of nature, can only be available for a few years to come.

The Colonial establishments were instituted at the instance of the Royal Society and British Association, with a more general concurrence and approval on the part of the cultivators of science in all parts of the globe than, it is believed, were ever before manifested in regard to any purely scientific undertaking ; and with such a cordial and effective cooperation of the public authorities as is well deserving of being held in remembrance. It is for those two great scientific bodies to consider whether any, and what, steps should now be taken to procure the continuance of the researches.

March 12, 1857.

Major-General SABINE, Treas. and V.P., in the Chair.

The following communications were read :—

I. "On the Immediate Principles of Human Excrements in the Healthy State." By W. MARCET, M.D., F.C.S., Assistant Physician to the Westminster Hospital. Communicated by H. BENCE JONES, M.D., F.R.S. Received February 23, 1857.

(Abstract.)

In a previous paper I had the honour of communicating to the Royal Society the results of a first series of investigations on the immediate principles of the faeces of man and animals ; since then I have continued my researches on human excrements, being most ably seconded by my assistant, Mr. Frederick Dupré, Ph.D.

The new results obtained were the following :—

1. *Margarate of lime, phosphate of lime, and margarate of magnesia* were discovered to be immediate principles of human evacuations.

2. I found a new method for obtaining excretine, and its chemical formula has been established.